National Aeronautics and Space Administration

Laboratory direct readout

*developing technologies for **real-time** collection, processing, and distribution of Earth science data*

The Direct Readout Laboratory (DRL) at NASA's Goddard Space Flight Center develops technologies to maximize the utility of Earth science data for real-time decision-making.

- The DRL serves as the bridge between user needs and mission objectives.
- The DRL's technology development process stresses continuity and standardization.
- DRL technologies enable instant access to instrument data and derivative products from the Aqua and Terra missions and, in the future, the NPP and NPOESS missions.
- DRL technologies are designed to be scalable, extensible, portable and easy to use.

LANCE UWG Briefing

Enabling Science to Applications

September 27, 2016

Patrick Coronado
Kelvin Brentzel
606.3

directreadout.sci.gsfc.nasa.gov

NASA Direct Readout Program

Vision

Unification of the global Direct Readout community for the understanding of Earth processes as a system

Mission Statement

Building upon NASA's mission #1: "To understand and protect our home planet", The Direct Readout Program's mission is to:

- Identify and understand the needs of a global community that use NASA's Direct Broadcast data.
  - Promote synergy between NASA, the community and interdependent direct broadcast data users
  - Act as a technical conduit between the mission and the public
- Guide direct readout community and NASA's Direct Broadcast Earth science missions.
  - Bridge mission planning based on lesson's learned and the establishment that use NASA Direct Broadcast
  - To provide technical and implementation insight to new missions that wish to use Direct Broadcast
  - Educate on the importance and utility of NASA's data
- Enable
  - The use of NASA's space-borne Earth science data
  - The commercial sector by offering non-recurring engineering technologies
  - Technologies for decision-support infrastructure
  - Technology solutions for real-time and regional applications
  - Continuity among missions to minimize end-user impact
  - Real-time applications support systems

Mission Implementation

Establish the Direct Readout Laboratory to serve as a focal point for:

- Promoting standardization in:
  - Direct readout pre-processing sub-systems
  - Direct readout science processing algorithms
  - Visualization and data processing systems
  - Real-time data/product transport methods and mechanisms
- Providing cross-cutting core competency in
  - On-board Direct Broadcast RF and data bus configurations
  - Data encoding/decoding schemas and instrument data formats
  - Real-time ground data processing systems
  - Real-time data dissemination systems
  - Computer science methods for standalone science algorithm implementation
  - Data loss risk reduction, fault detection and resolution
  - Real-time In-Situ data gathering for calibration and validation campaign
  - Risk reduction at the satellite mission level
- Real-time mission operations support for problem resolution and characterization
- Provide enabling technologies to the global community via Public Release
- Promote international collaboration to identify and establish methods for technology and data exchange
- Providing cost-saving solutions for the acquisition, processing and distribution of directly broadcasted data via technology enabling
- Real-time applications for decision support tools

DRL Contributions to Terra

-- Continuity --

- Worked cooperatively with commercial sector to develop a basis for DB acquisition. Vendors invested their own R&D dollars NASA and colleagues procured COTS. From $1.5M to $150k cost savings.
- Defined a generalized template for broader user community to build their own DB acquisition capability
- DRL received the first DB transmission and worked with System Engineers and Mission Ops Team to commission this new service.

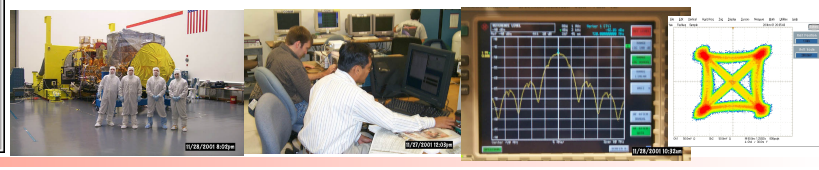
http://earthobservatory.nasa.gov/Features/Blizzard/

- Since, the DRL provides algorithms, technologies/tools, ancillary data, documentation, etc.

DRL Contributions to Aqua

-- Continuity --

- Continued to build on the model previously created for Terra.
- The Mission requested even more intimate involvement by DRL in ascertaining user need and impact mitigation. DRL served as intermediary between mission team and end-user global community
- DRL cajoled the commercial sector and involved them in receiver verification on-site at TRW (now NGST) Redondo Beach.
- Successfully built upon technologies adopted by commercial and end-user to become the basis for EOS direct readout capability
- Continue to provide technologies, algorithms, ancillary data and documentation



DRL Contributions to SNPP

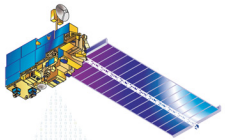
-- Continuity --

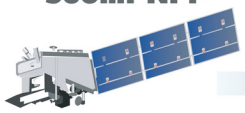
- DRL was engaged by the NPP pre phase A Team to contribute to the Outreach (education) element of the mission.
- As a member of the project was involved in all aspects of communication and instrument payload trade study.
- Defined the spec and procurement for what is now known as RF Suitcase at Svalbard.
- Participated in all engineering opportunity and NCTs in the master mission schedule.
- Developed the template for direct readout acquisition. And not only was DRL the first to receive NPP direct broadcast transmission but also fully characterized HRD antenna pattern on-orbit and identified what is now known as the SNPP antenna anomaly. Fixed in JPSS-1.
- First to produce suite of L2/EDR products from the direct broadcast downlink. DRL Team received public high praise from Mr. Ken Schwer!
- Continue to provide technologies, algorithms, ancillary data and documentation

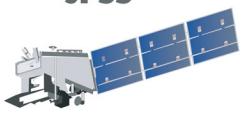
JPSS-1 Scope: Work in Process

- Consult in the development of JPSS Inter-segment ICDs, IRDs and ConOps document development for HRD
- Prelaunch (eg. SI&T phases) provide software preprocessor (RT-STPS) software to flight team for acquisition and real-time data dissemination of SMD and HRD data units (RDR/PDS). Enhanced capabilities provided where needed.
- Select Algorithm Porting and Sustainment (execute outside institutional system)
- L&EO HRD downlink (RF and baseband) monitoring/characterization (acquisition at the GSFC)
- Redistribute mission ancillary and axillary data (eg. Algorithm execution)
- Release and maintain relevant mission docs to the public
- Release and maintain designated mission science algorithms to public

DIRECT READOUT TECHNOLOGY ROADMAP







AVHRR
SeaWiFS
OLS
HIRS
SSM/I, SSMIS, SSM/T, SSM/T-2

MODIS

MODIS
AIRS
AMSU
HSB
AMSR-E

VIIRS
CrIS
ATMS
OMPS

VIIRS
CrIS
ATMS
OMPS

Spacecraft and Instrument Evolution

L-Band, S-Band
665 - 2 Mbps
BPSK

X-Band
13.1 Mbps
Convolutional
UOQPSK
NRZ-M

X-Band
15 Mbps
OQPSK
NRZ-M

X-Band
15 Mbps
Convolutional
QPSK
NRZ-M
Compression

X-Band, L-Band
15 Mbps/3[illegible] Mbps
Convolutional
QPSK
NRZ-M
Compression

Standardization and Increasing RF, Modulation, and Bandwidth Requirements

- Custom Formatters and Ingest Software
- Analog Custom Receivers
- NOAA Level B (AVHRR)
- Limited Data Distribution Mechanisms

- Spacecraft Specific STPS
- Level-0
- Return Link Processor
- Analog Configurable Receivers
- MODIS Level-1
- MODIS Simulcast

- Reconfigurable RT-STPS
- Return Link Processor
- Digital Configurable Receivers
- MODIS and AIRS Level-1
- NEpster with Level-0 and Level-1 Data
- MODIS Simulcast

- User Reconfigurable RT-STPS
- Multi-Mission Digital Receiver
- Instrument SDR Software and Select EDR Algorithms
- NEpster with RDR, SDR, and EDR Data Products
- IPOPP Framework
- Simulcast of Select Instruments

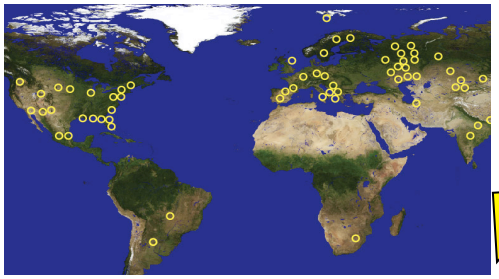
Evolution of Concurrent Ground Systems Supporting Technologies and Algorithm Development

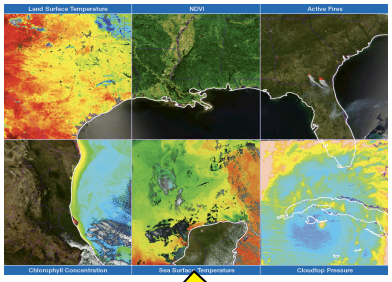
DIRECT READOUT LABORATORY
directreadout.sci.gsfc.nasa.gov

The State of NASA Direct Readout Program 2016

34 L2 DB Science Algorithms and Data Tools

220 DR Ground Stations





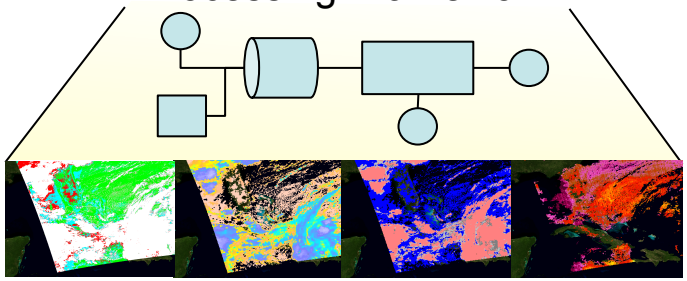
10 Operational Applications

NASA's DB Program

Discipline-based Steering Committees for Applications

International Collaborations

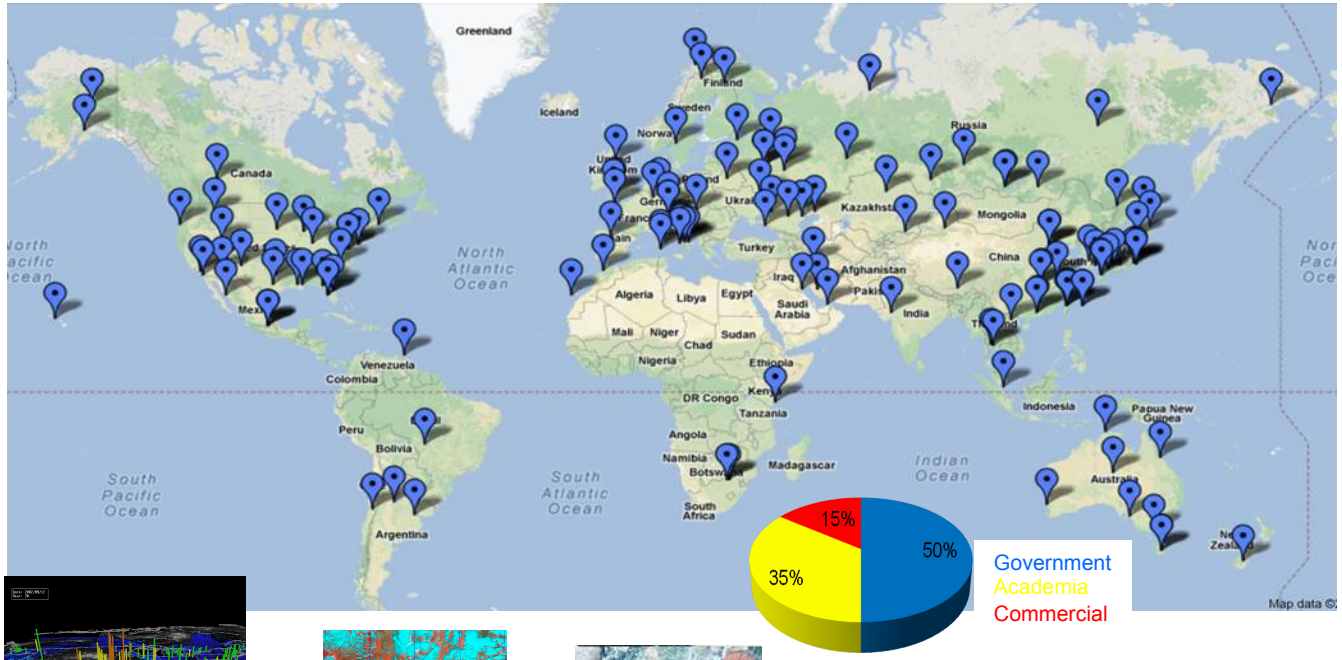
Real-time Science Processing Framework



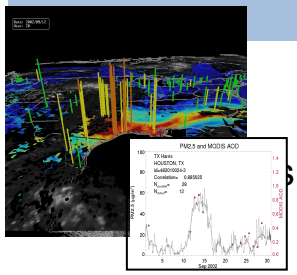
L2 DB Science Products

Over 3000 Registered Users and Over 6,000 Software Downloads

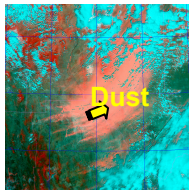
EOS/S-NPP Direct Readout Users and Their Support System Applications



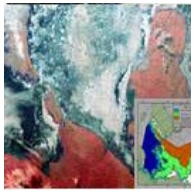
- **Over 220 acquisition sites**
- **All sites use NASA algorithm/tools.**
- **85% support real-time applications.**
- **Over 3000 registered users**



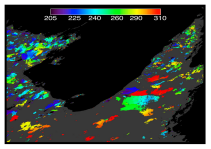
Aerosol –Air Quality



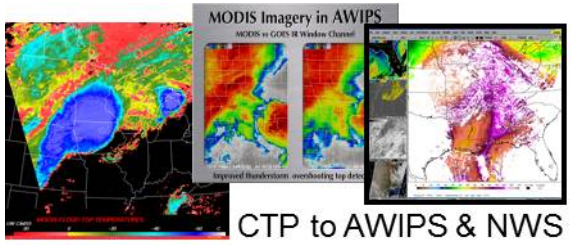
Dust Tracking



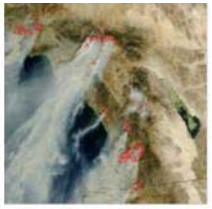
Sea Ice Navigation



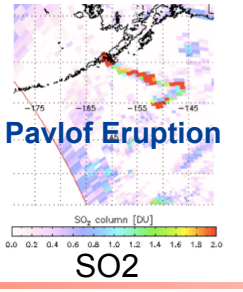
Burned Area



CTP to AWIPS & NWS



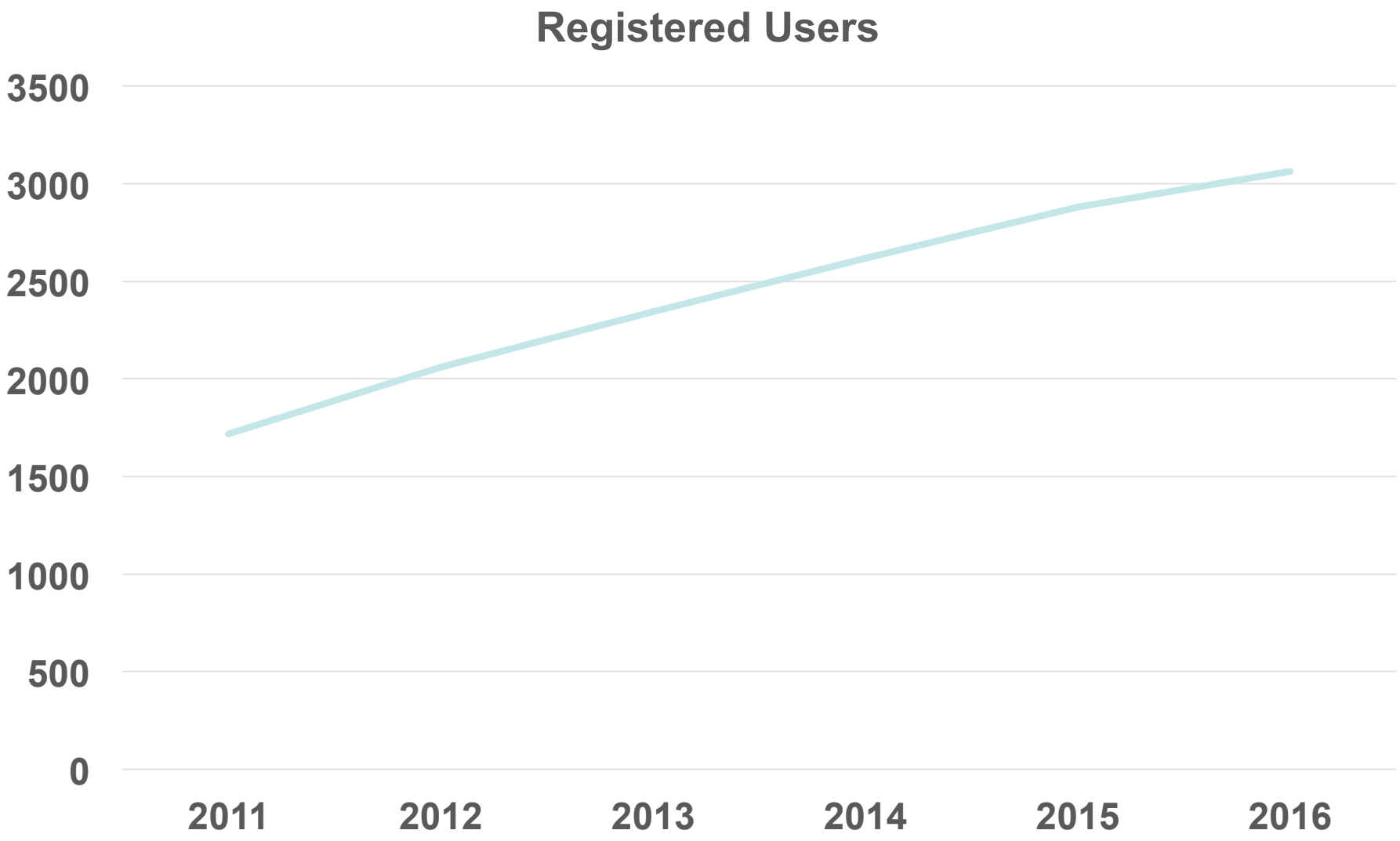
Active Fires



SO2

- Fire detection, burned area and Corrective Reflectance science algorithms for the generation of fire perimeter mapping & damage assessment
- SO2/Ash - Air quality monitoring and tracking via the use of MODIS and VIIRS DB with the OMPS SO2, Fire, Corrective Reflectance and Imagery algorithm.
- DoD – Navy Research Lab (NRL) real-time plume and dust storm maps to support airborne missions.
- Operational real-time generation of Cloud Top Temperature (NASA's MODIS CTP algorithm) for insertion into DoD's AWIPS forecast weather system for severe thunderstorm top detection and tracking.

User Trend since SNPP Launch



DRL Web Portal Users

Total Number of Registered Users = 3063, from 100 countries

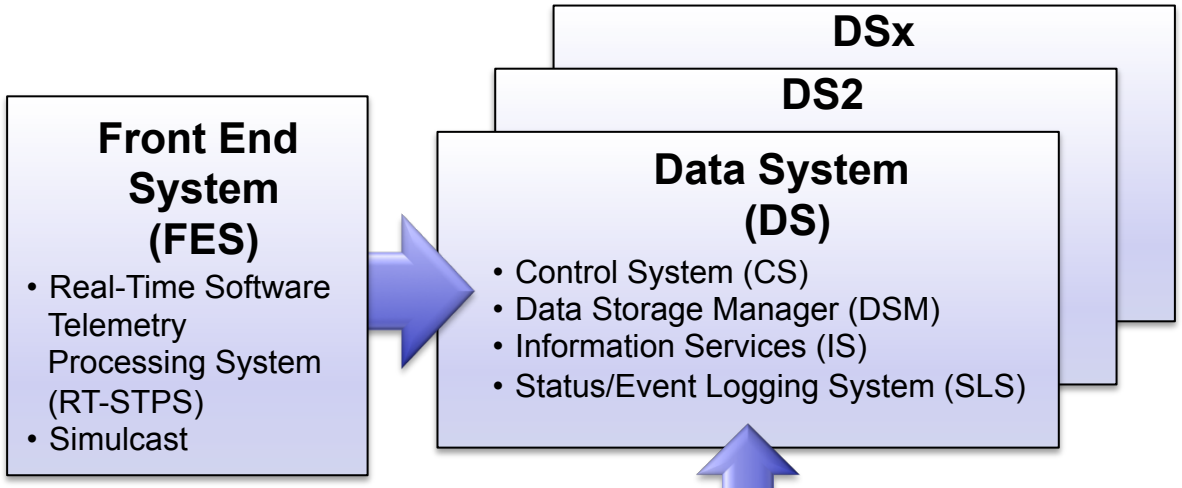
COUNTRY	USERS
Argentina	40
Australia	108
Belgium	12
Brazil	65
Bulgaria	19
Canada	59
Chile	14
China	238
Denmark	11
France	52
Germany	69
Greece	20
Hong Kong	10
India	94

COUNTRY	USERS
Indonesia	51
Iran	35
Italy	90
Japan	128
Kazakhstan	10
Kenya	10
Malaysia	30
Mexico	35
Netherlands	17
Nigeria	10
Norway	23
Pakistan	13
Peru	10
Poland	11

COUNTRY	USERS
Portugal	12
Romania	12
Russia	150
Singapore	25
South Africa	21
South Korea	36
Spain	48
Taiwan	27
Thailand	24
Turkey	14
Ukraine	23
UK	105
US	987
Vietnam	22

Note: Countries with less than 10 registrants are not listed

IPOPP Framework Hosting PI SPAs



Science Processing Algorithms (SPAs)

GTMIMAGERY
ACTIVEFIRES
AEROSOL
LST
SNOWCOV
SURFREFLECT (Surface Reflectance)
VEGINDEX
COP (Cloud Optical Properties)
CLOUDMASK
C-SDR (VIIRS, CrIS and ATMS)

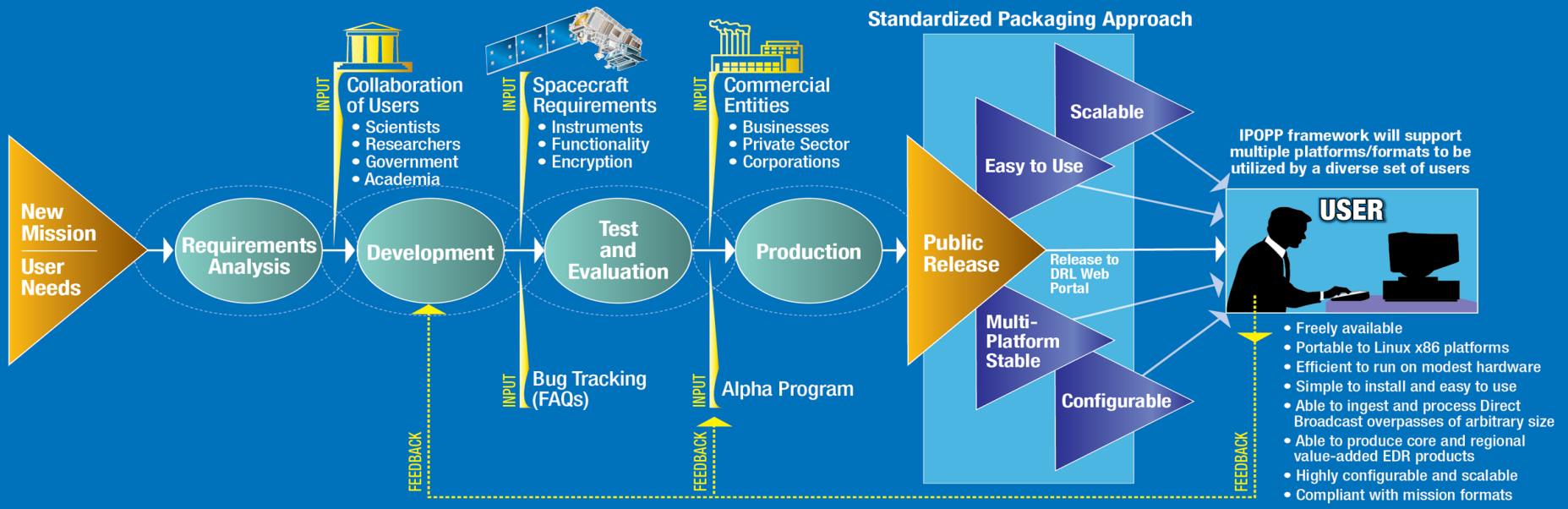
H2G (Visualization & Formatting Tools)
Blue Marble (enhanced)

VIIRS-AF
OMPSNadir
VFIRE375
VIIRS-SDR (Land SIPS RDR/SDR/GEO)
CREFL (Corrected Reflectance-True Color Sharpening)
CVIIRS (Corrected Reflectance-True Color Sharpening)
ATMS and CrIS Imagery (All Bands Brightness Temperature)

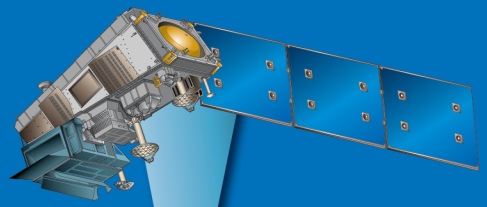
IPOPP & SPAs available for download:
http://directreadout.sci.gsfc.nasa.gov

IPOPP Development Methodology

Users are an integral part of the development process



IPOPP Context to SPAs



Direct Broadcast Data Stream

Real-Time Instrument-specific Data Streaming

Pre-Processing

- Packet Processing
- RDR/Level 0 Formatting
- Real-Time Instrument Data Streaming

DR Processing Environment

SPA Environment

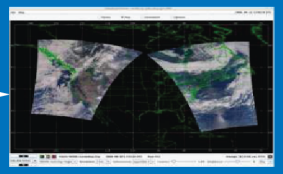
Science Algorithm

Anc/Aux/IPs Data Input

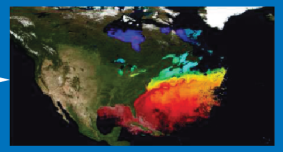
Product Reformatting

HDF to GeoTIFF

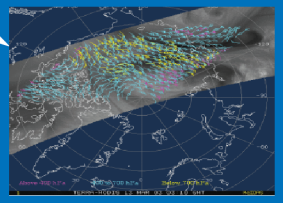
RT Cluster Process Monitoring



Remote Real-Time Data Viewing

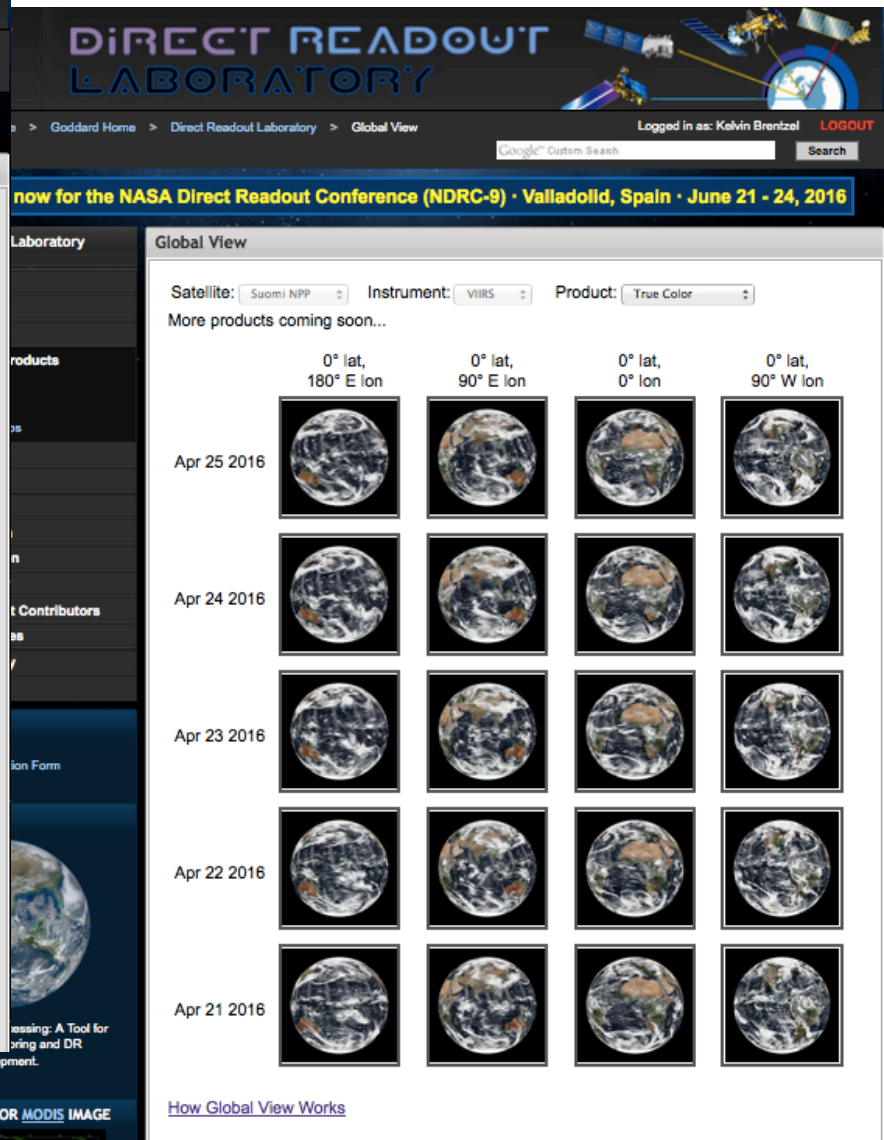


Portable Data Products



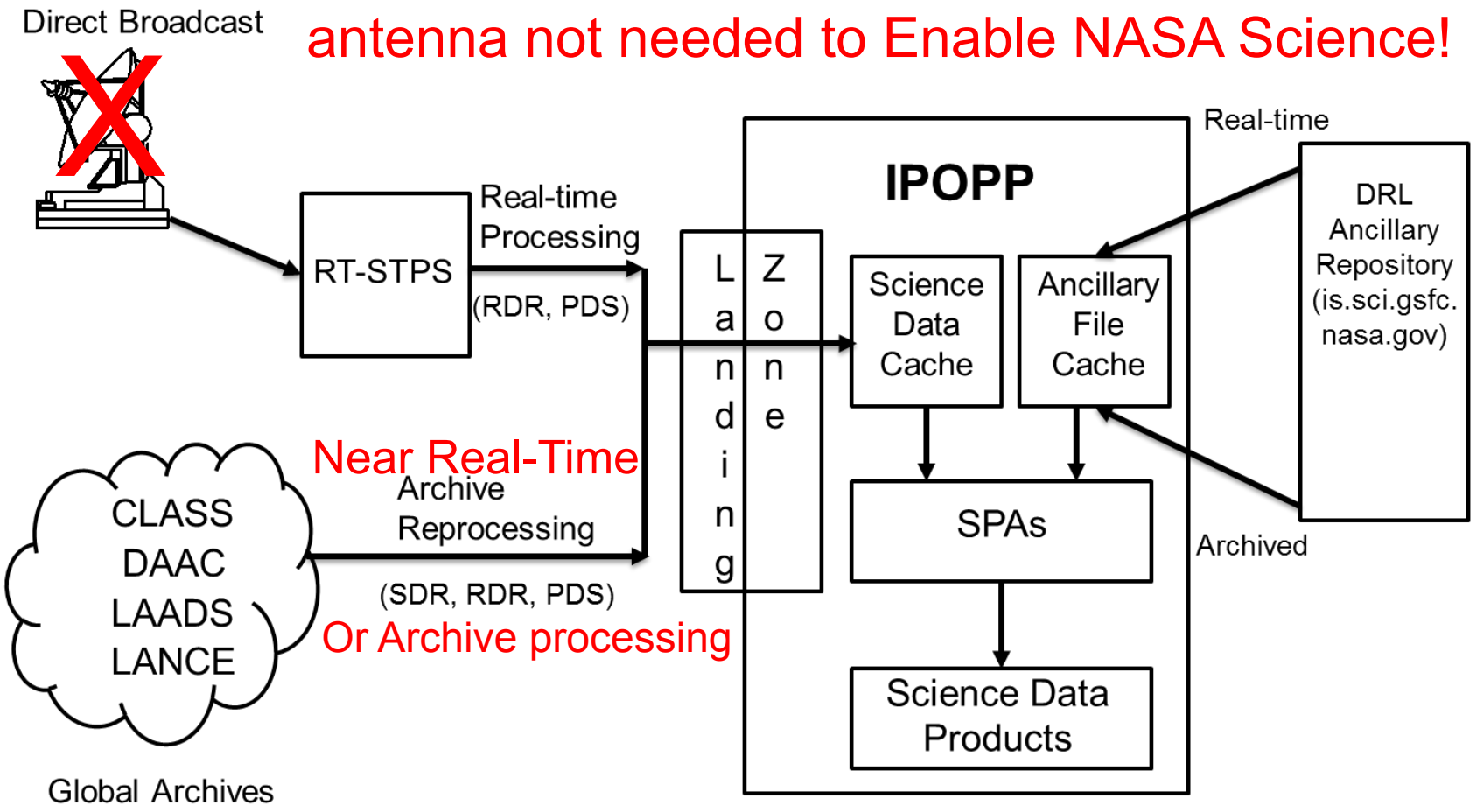
Visualization and Analysis

Testbed Environment for Algorithm Evaluation

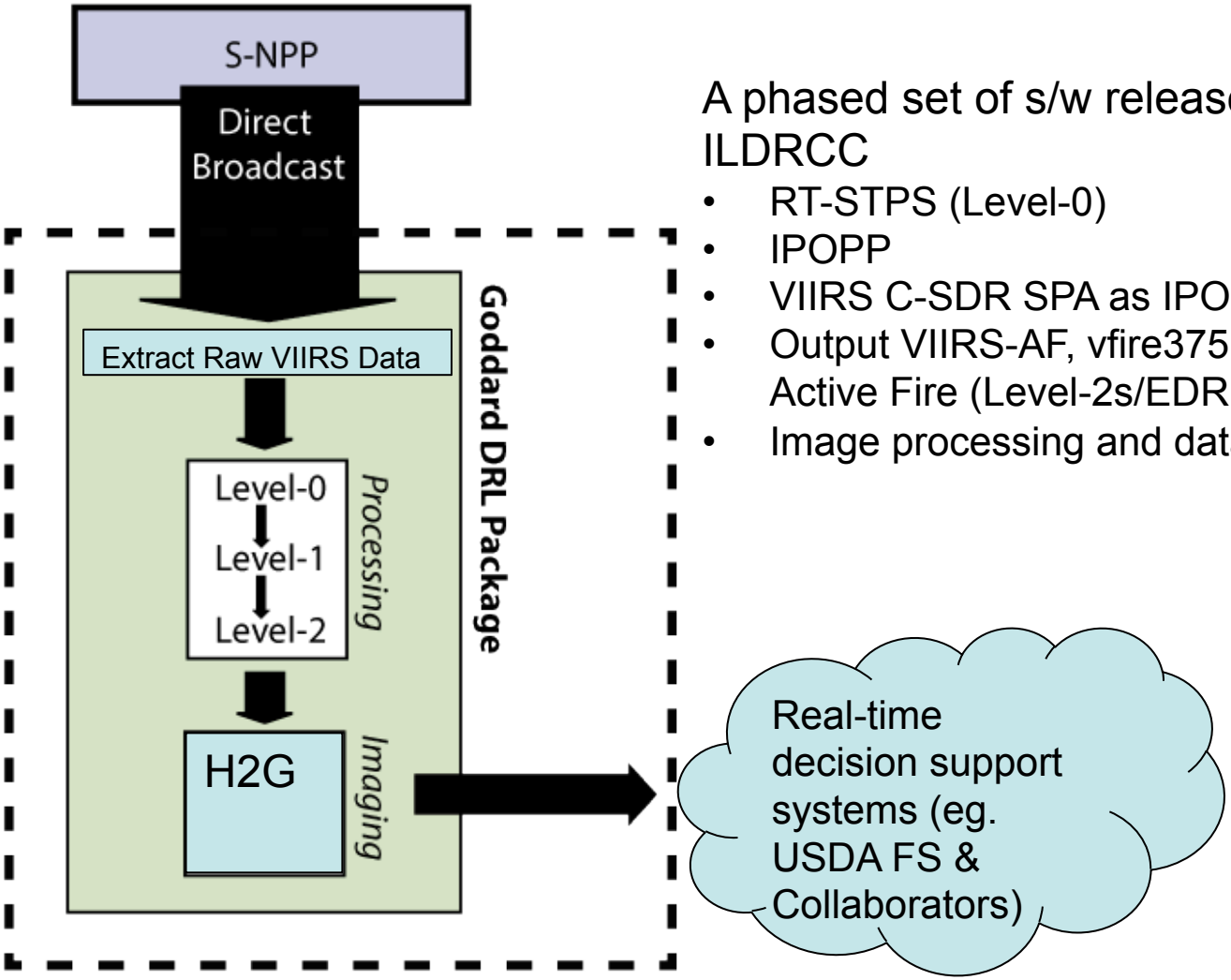


Enabling Science Context

Outreach -- Enabling Science to Applications



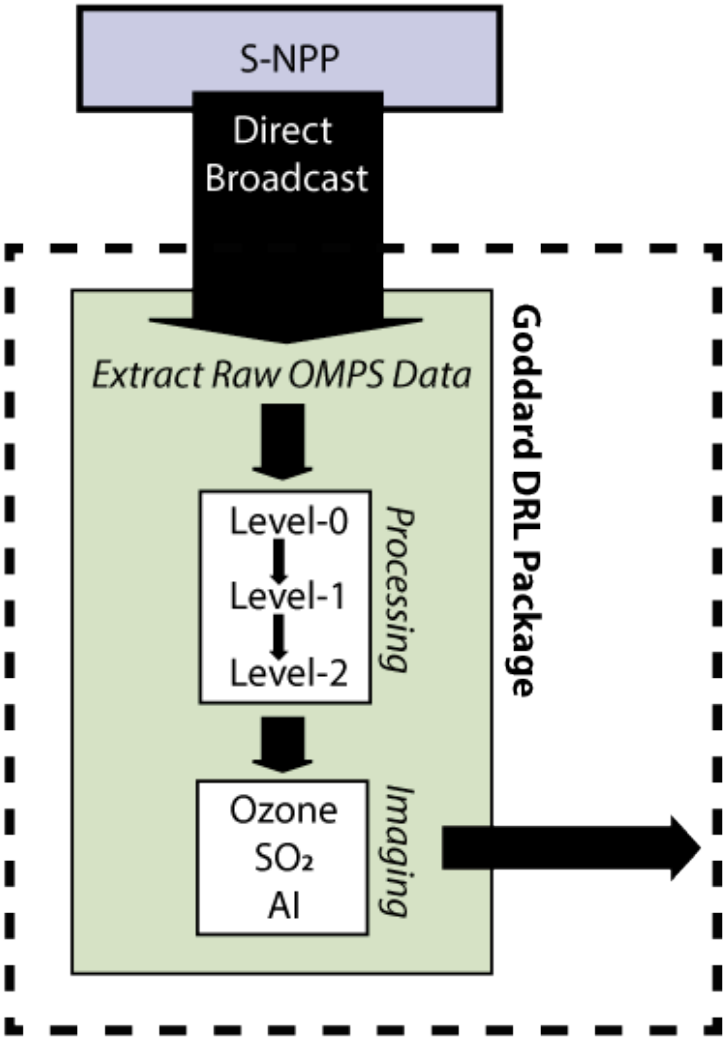
Support of Algorithm Implementation
VIIRS I-Band Active Fire (NASA vfire375)



A phased set of s/w releases by the DRL to the ILDRCC

- RT-STPS (Level-0)
- IPOPP
- VIIRS C-SDR SPA as IPOPP plug-in (Level-1)
- Output VIIRS-AF, vfire375 and NOAA operational VIIRS Active Fire (Level-2s/EDR)
- Image processing and data product intercomparison

Support of Algorithm Implementation
OMPS SO2 and AI (NASA OMPSNadir)



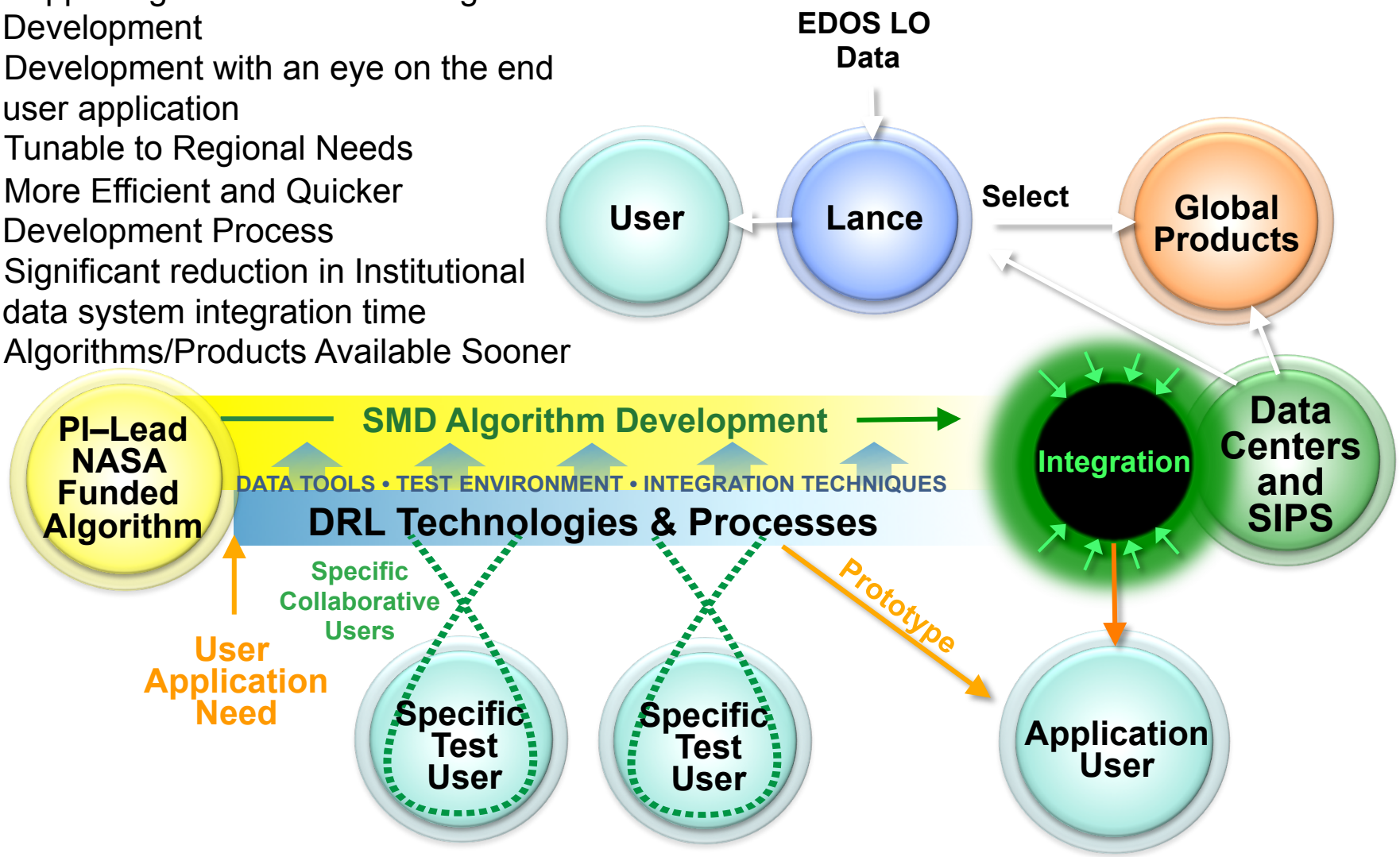
A phased set of s/w releases by the DRL to the FMI and GINA

- RT-STPS (OMPS RDRs)
- IPOPP OMPS L1A SPA as IPOPP plug-in
- OMPS L2 SPA for SO2
- OMPS L2 SPA for AI
- Image processing and data product distribution

Real-time decision support systems (eg. USGS, AVO, Air Navigation)

DRL Role in Science Algorithm Public Access

- Supporting NASA funded PI Algorithm Development
- Development with an eye on the end user application
- Tunable to Regional Needs
- More Efficient and Quicker Development Process
- Significant reduction in Institutional data system integration time
- Algorithms/Products Available Sooner



DRL User Support Tools:
Enhancing Utility of Standard Products

BlueMarble

A Tool for Bridging Science to Applications

BlueMarble: An Applications Research and Analysis Software Package

Science Data Products

Aqua MODIS
Terra MODIS
SNPP VIIRS
SNPP ATMS
SNPP CrIS
SNPP OMPS
Other Sensor

- Multi-Mission Multi-Sensor

Pre-processing

- Can Be Used Standalone or as IPOPP Plug-in
- Enables Data Discovery
- Simple Command Line Interface; Allows Incorporation Into Other Packages
- Focuses on Interoperability

- Metadata Check
- Adjacency Determination
- Data/Sensor Identification and Configuration
- Region-of-Interest/Swath Overlap Determination

Processing

Quality Control
Image Enhance-ments
Projection & Vector Overlays
Correction/ Adjustment
Background Imagery
CORE UTILITIES
Subsetting & Mosaicing
Application-Specific Modules

Application Imagery/ Data Products

Applications

- Produces GIS Compatible GEOTIFF Products
- Enables Real-Time Applications

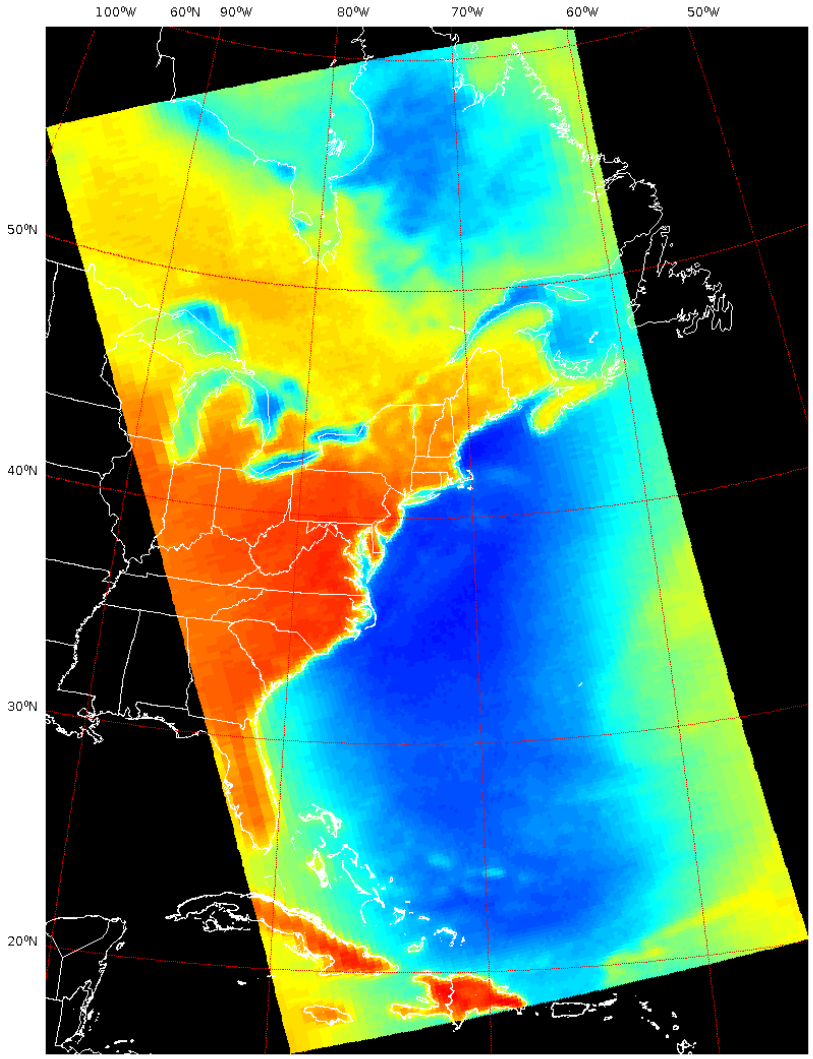
SCIENCE **Promotes** **Collaboration** APPLICATIONS

Image Products from BlueMarble

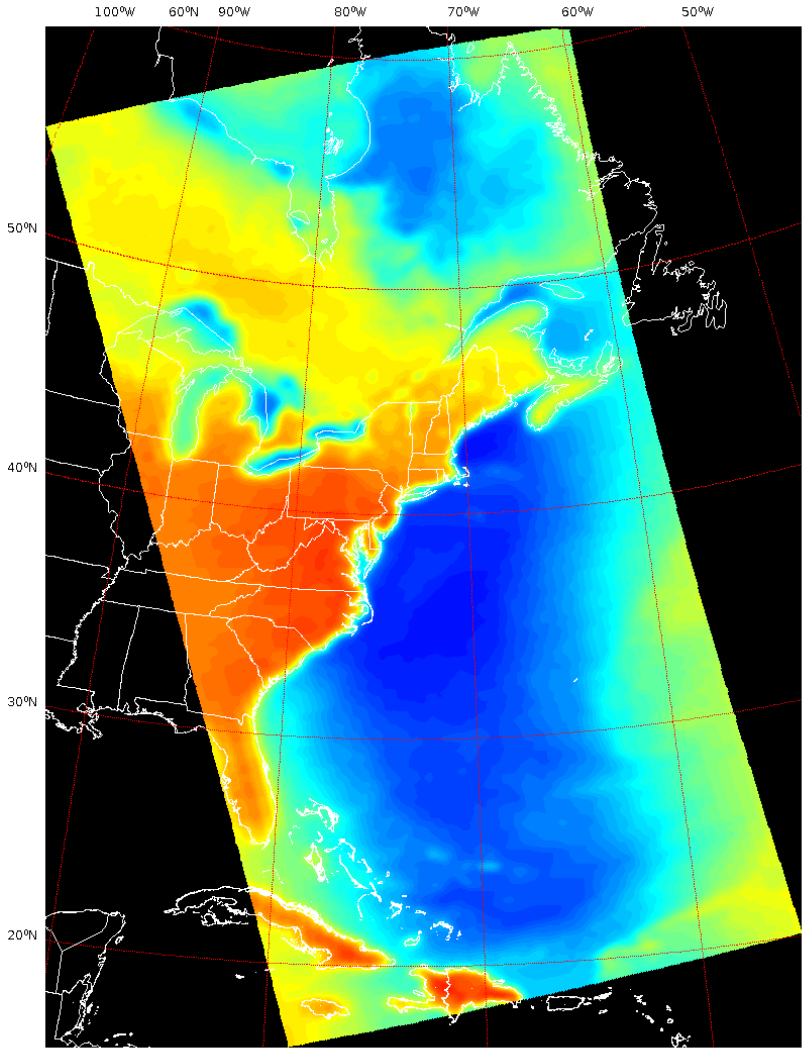
www.nasa.gov
directreadout.sci.gsfc.nasa.gov

DRL Data Tools

Outreach -- Enabling Science to Applications



BEFORE

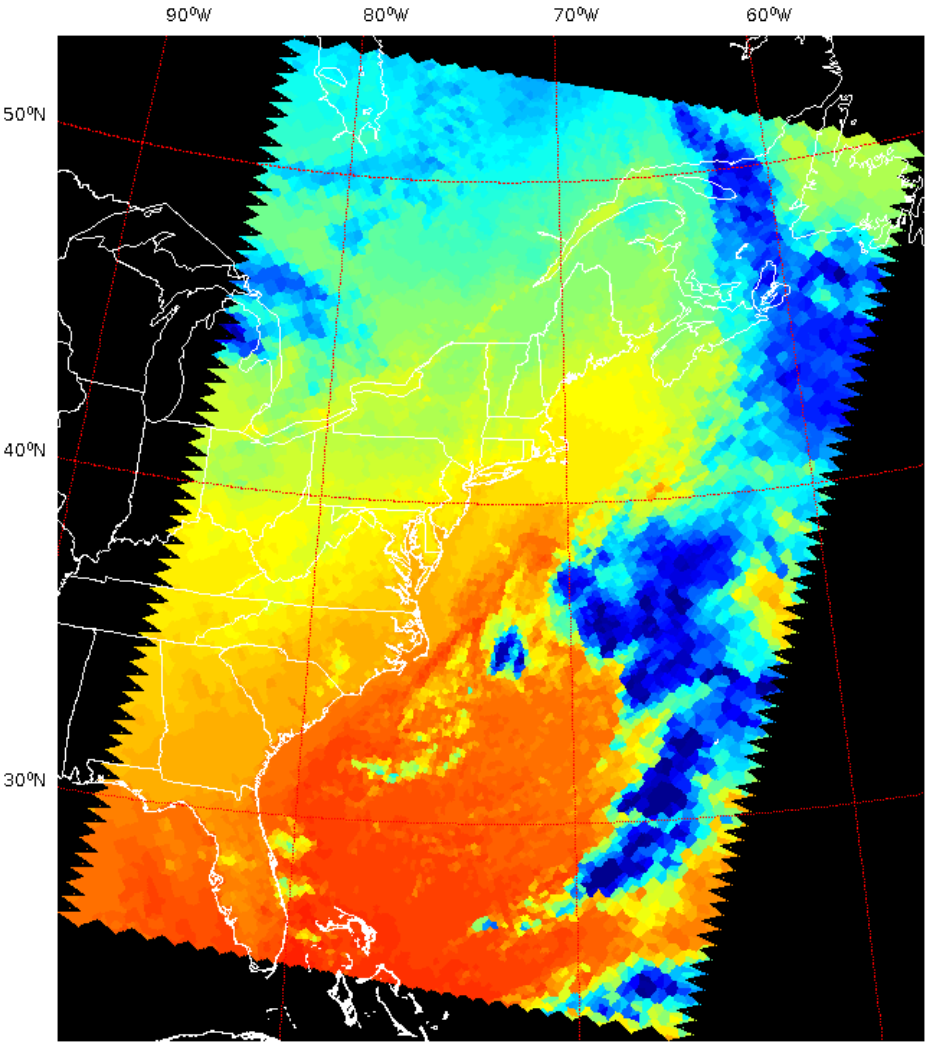


AFTER: Applying Inverse Distance Weighted Interpolation and Mean Filter Smoothening

ATMS Channel 3 Brightness Temperature 04/25/2016, 17:43 UTC

DRL Data Tools

Outreach -- Enabling Science to Applications



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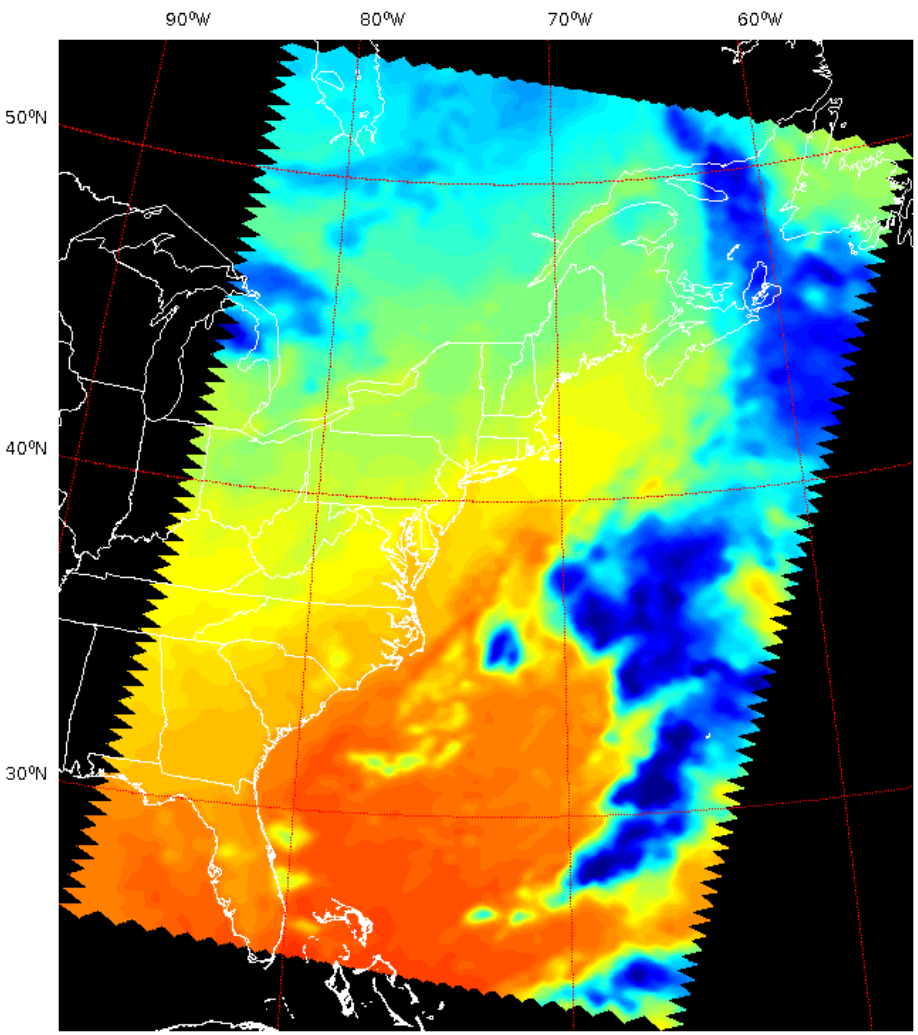
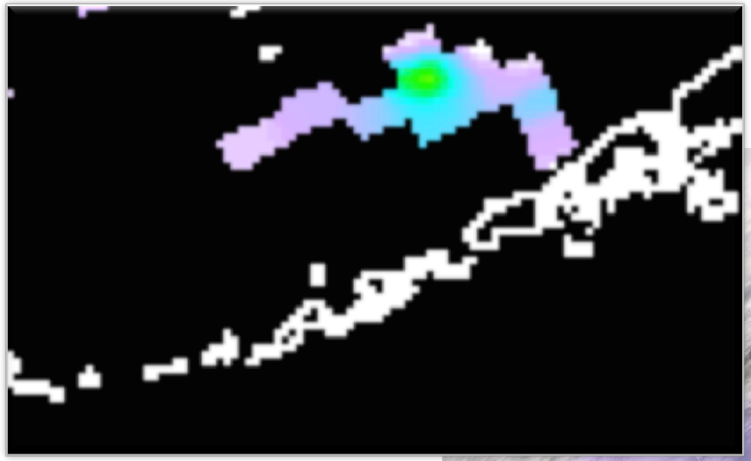


AFTER: Applying Inverse Distance Weighted Interpolation and Mean Filter Smoothening

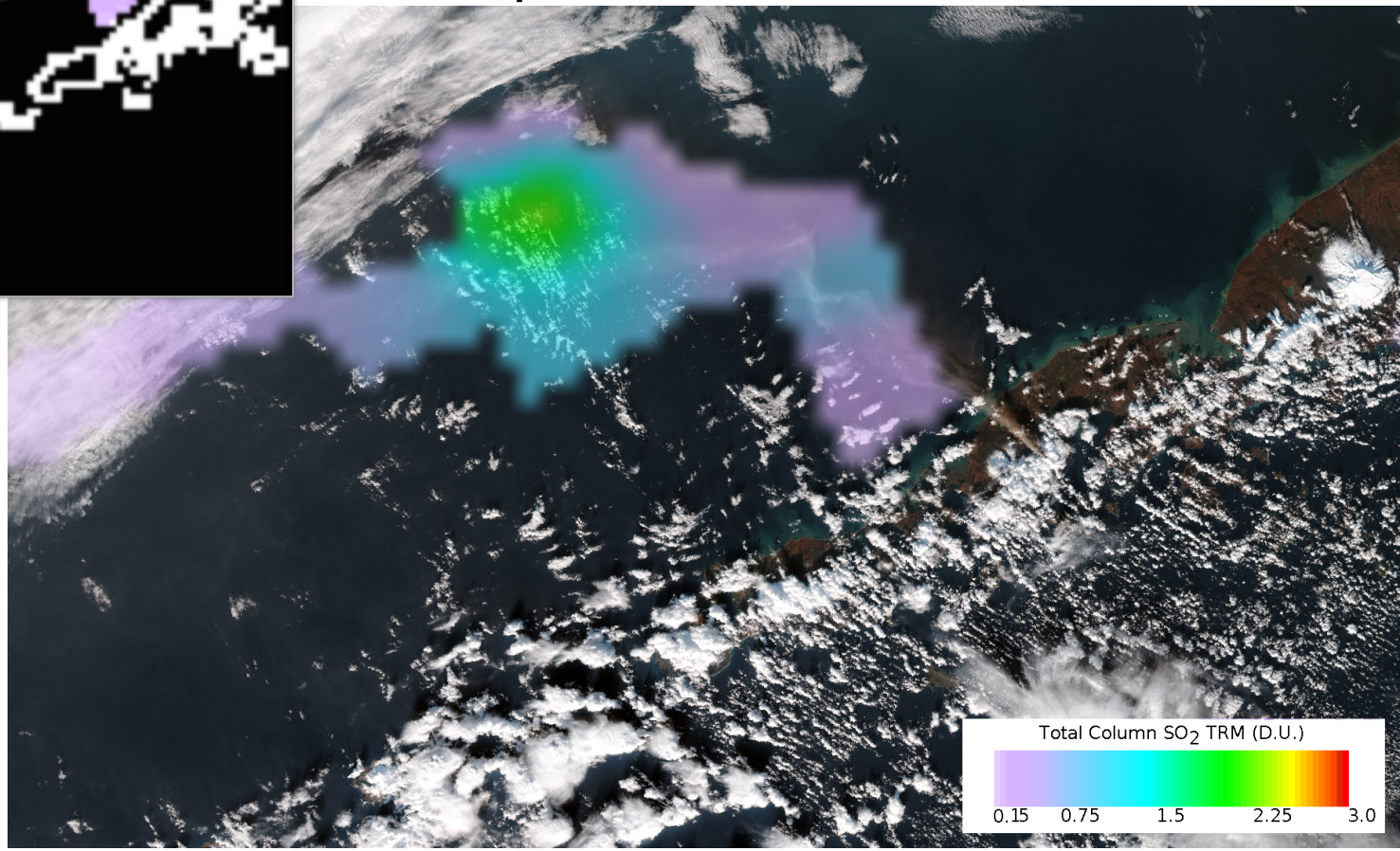
DRL Data Tools

Outreach -- Enabling Science to Applications

BEFORE: Standard Product



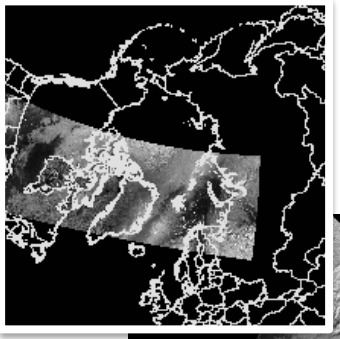
AFTER: OMPS SO_2 overlay on VIIRS Sharpened True Color



VOLCANO PAVLOV ERUPTION, ALASKA, 14 NOV 2014

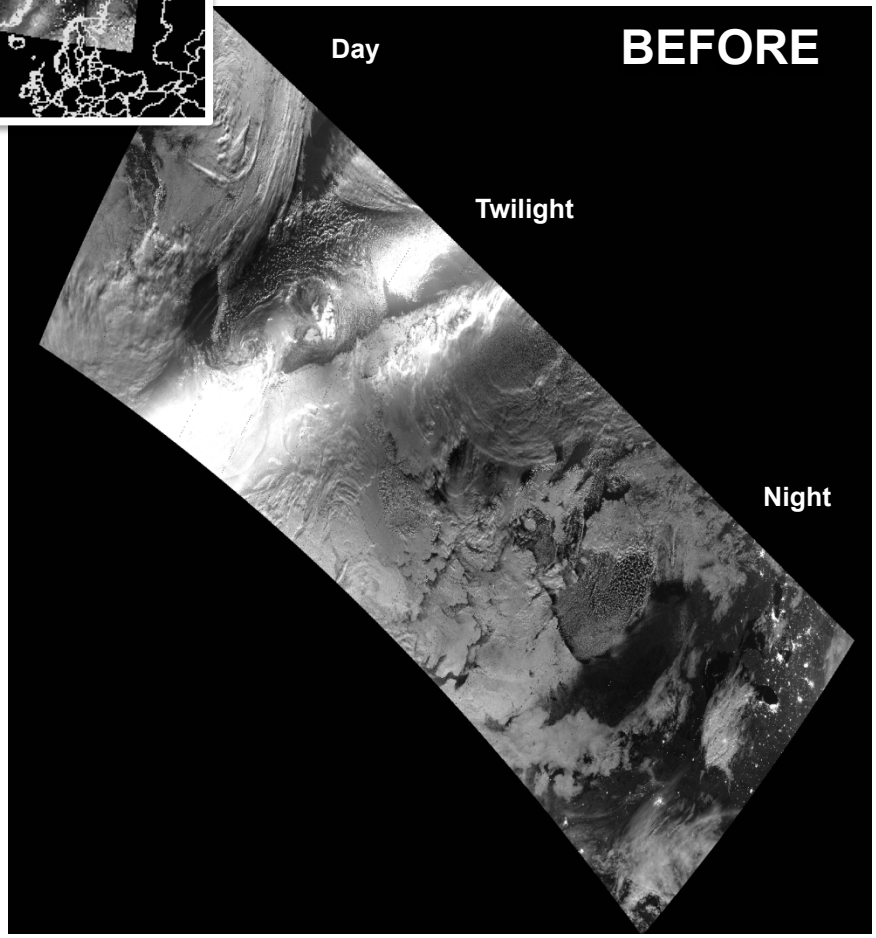
DRL Data Tools

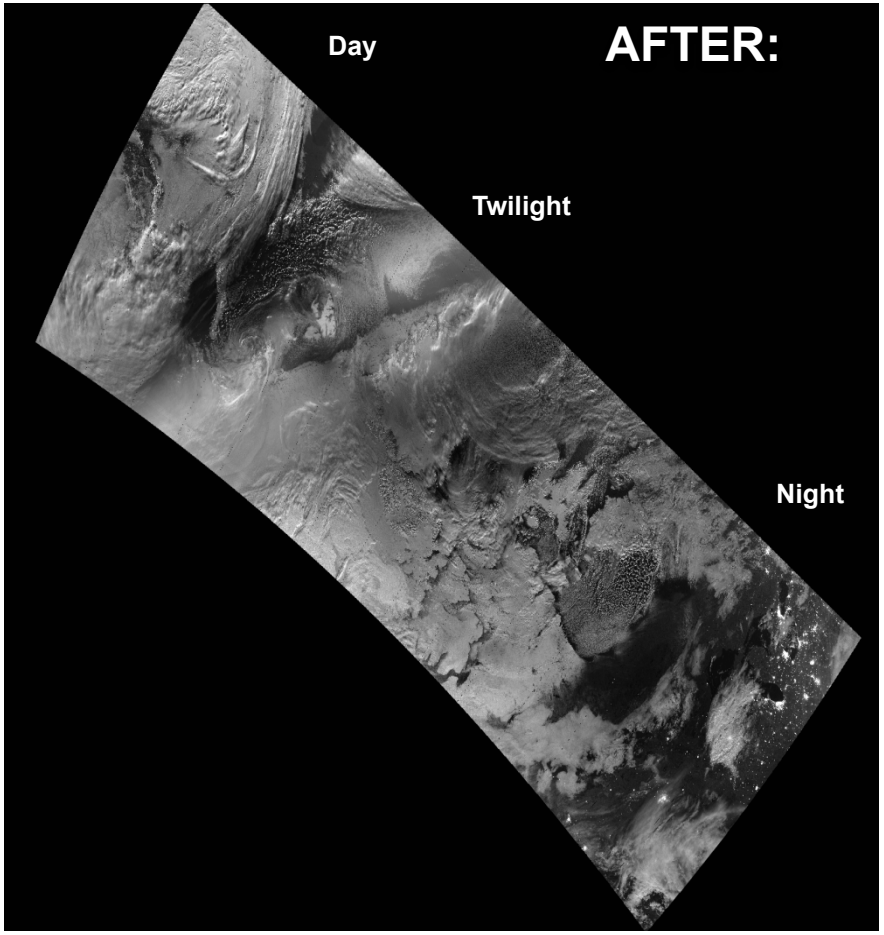
Outreach -- Enabling Science to Applications



Solar and Lunar corrections, ENCC (Extended NCC)

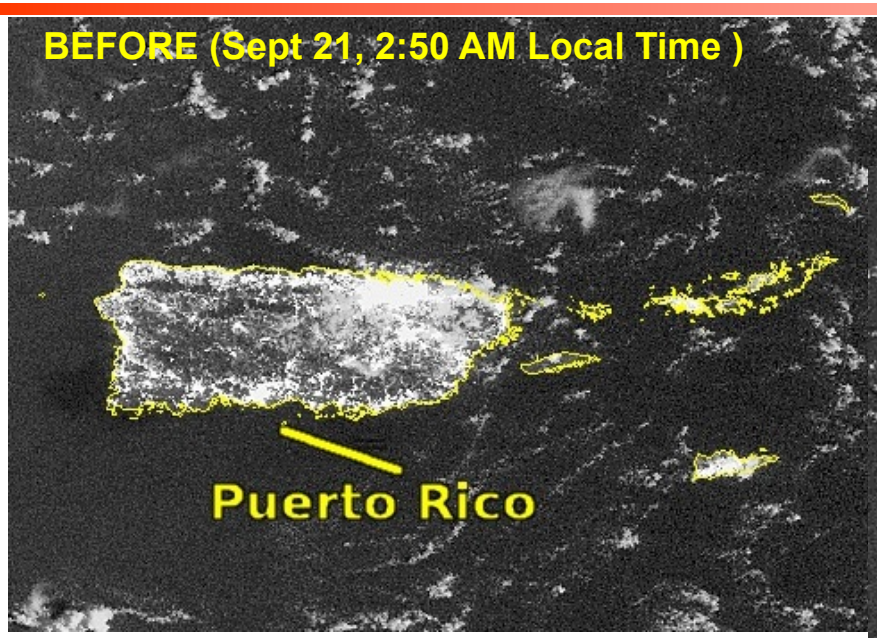
Oct 26 2015; UTC 08:01 – 08:22

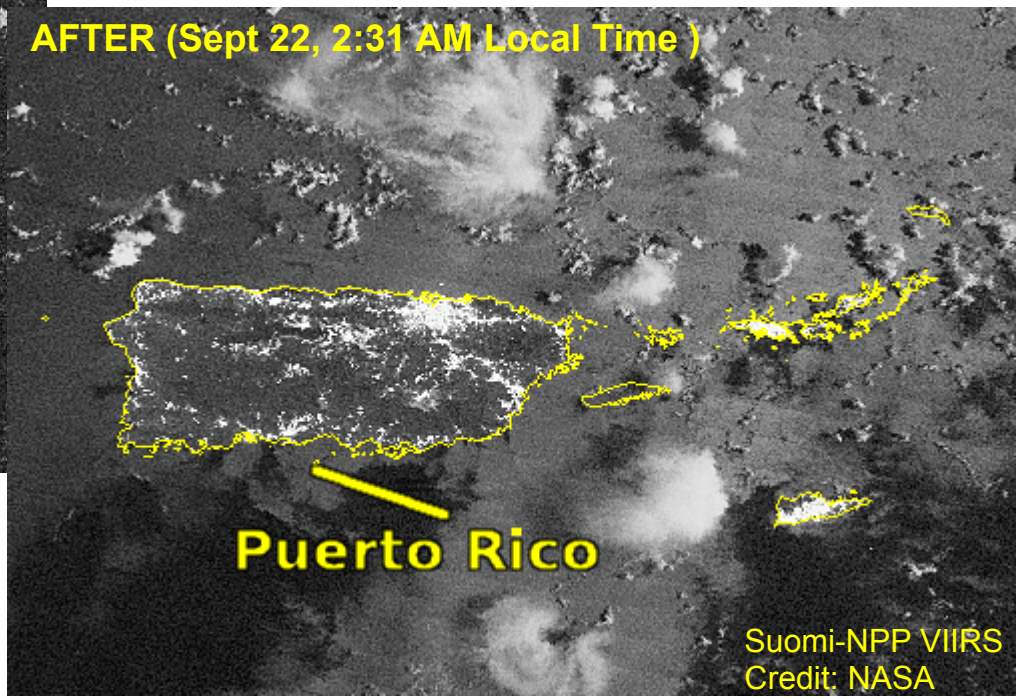




Note: Twilight region has about 58% cloud coverage

NASA Disasters Response Program
Puerto Rico Power Outages (Sept 21-22, 2016)





- On September 21st, 2016 a major power outage was on the island of Puerto Rico (PR).
- The island's power company (PREPA) said the outage is affecting customers throughout the island.
- The Puerto Rican paper El Nuevo Día reports that 1.5 million customers are without power owing to the "complete collapse of the system." The paper reports the outage was caused by a fire at a substation at the Aguirre power station in Salinas, PR.

- Nighttime satellite imagery of the Puerto Rican archipelago shows the extent of outages across major urban areas outside of the San Juan Metropolitan Region. These include the cities of Ponce, Humacao, Aguadilla, Arecibo, Mayagüez, and the Island of Vieques. The images were released by NASA and can be used to track restoration progress.

NASA Direct Readout Conference – 9

NDRC-9 took place June 21st – 24th, 2016 at Valladolid, Spain

Host : Laboratorio de Teledeteccion (LATUV) – University of Valladolid

Sponsors/Organizing Committee*:
- EUMETSAT* (ITWG)
- WMO
- USDA Forest Service* (ILDRCC)
- Oregon State University* (IDROSC)
- University of Wisconsin/SSEC* (ITWG)

Registered Attendees: 180
- 35 countries represented

Structured to provide Plenaries and Workshops

Plenaries for the world to present what they are doing with NASA's data

Workshop to further enable NASA's data use for decision support systems

Presentations/Posters/Proceedings

https://directreadout.sci.gsfc.nasa.gov/?id=dspContent&cid=244

Thank you!

NASA Direct Readout Program - DRL

The Direct Readout Laboratory (DRL) acting as the implementation arm of NASA's Direct Readout Program endeavors to:

Enable:

- The utility of NASA's Earth science data
- Technologies for decision-support infrastructure
- Real-time monitoring of S/C data integrity and backup data source
- Technology solutions for real-time and regional applications
- Continuity among missions to minimize end-user impact
- Real-time applications support systems

Provide:

- Ported science processing algorithms for DB applications
- A direct readout test environment for the commercial sector
- End-to-end prototype direct readout ground station
- Data transport tools for NASA's Earth science data
- Real-time data processing tools that are modular, scalable, portable & extensible
- Utility via the promotion of standards in pre processing sub-systems, Science Processing Algorithms (SPAs), visualization and real-time processing systems

NASA Direct Readout Program – DRL (Cont.)

Identify and understand the needs of a global community that use NASA's Direct Broadcast data:

- Promote synergy between NASA, the community and interdependent direct broadcast data users
- Act as a technical conduit between the mission and the public

Guide the direct readout community and NASA's Direct Broadcast Earth science missions:

- Bridge mission planning based on lesson's learned and the establishment that use NASA Direct Broadcast
- To provide technical and implementation insight to new missions that wish to use Direct Broadcast
- Educate on the importance and utility of NASA's data

DR Algorithms / Support Tools Available to Public (Multi-misson)

Algorithms for direct broadcast data (SPAs):

- Fire Detection – MODIS/VIIRS
- Vegetation Index – MODIS/VIIRS
- Enhanced Vegetation Index - MODIS
- Surface Albedo – MODIS/VIIRS
- Surface Reflectance – MODIS/VIIRS
- Sea Surface Temperature – MODIS/VIIRS
- Sea Ice - MODIS
- Snow Cover – MODIS/VIIRS
- Chlorophyll-a Concentration – MODIS/VIIRS
- Cloud Mask – MODIS/VIIRS
- Suspended Matter – MODIS/VIIRS
- Cloud Optical Thickness – MODIS/VIIRS
- CloudTop Pressure – MODIS/VIIRS
- Cloud Top Temperature - MODIS
- Aerosol – MODIS/VIIRS
- Aerosol Particle Size – MODIS/VIIRS
- Effective Particle Size - MODIS
- Cloud Top Properties and Cloud Phase – MODIS/VIIRS
- Atmospheric Profiles - MODIS
- Water Vapor - MODIS
- Land Surface Temperature MODIS/VIIRS
- Corrected Reflectance MODIS/VIIRS
- True Color – MODIS/VIIRS
- Geo-registration and Calibration (SDR) - VIIRS
- SO2 and AI – OMPS

Data Processing and Science Algorithm support tools:

- Blue Marble v1.5 (IPOPP Alpha Users as well as ILDRCC, IDROSC and ITWG)
  - True Color Sharpening, Extended NCC, Dynamic ROI (disasters)
- International Polar-Orbiter Processing Package (IPOPP) v2.5
- Real-Time Satellite Telemetry Processing System (RT-STPS) v5.8
- HDF to Geo-Tiff converter and Image Processor / Reformatter GIS ingestible (H2G)
- Mission Data Format Converters